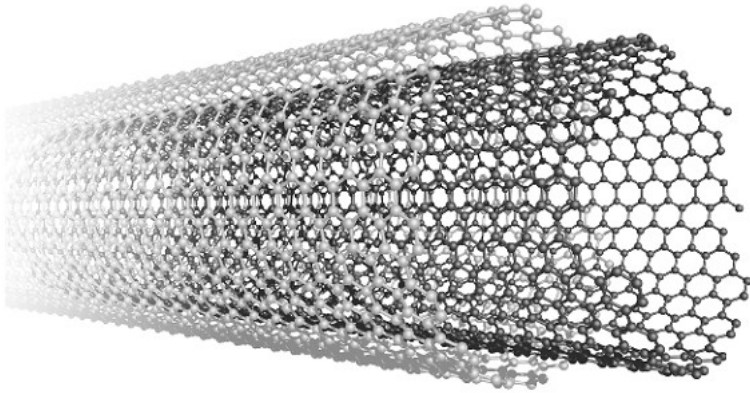


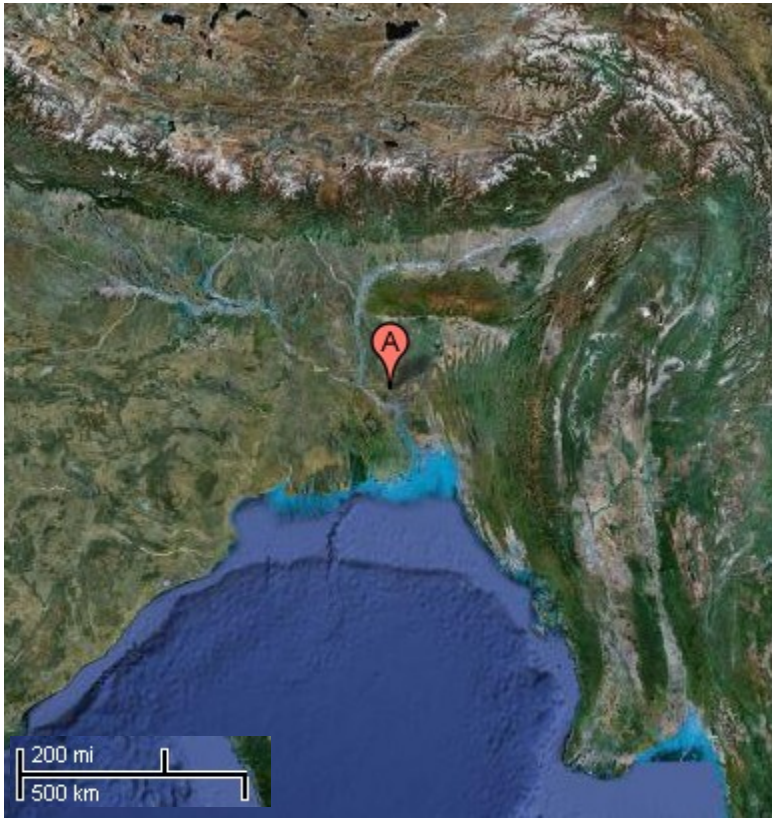


Lecture 1

Introduction

Dr. Mashiur Rahman

Introduction to Nano-scale systems



Bangladesh



Dhaka



Dhaka city



National Parliament



Lake



Tree top



1 meter

Oak branch and leaves



100 millimeters

Oak leaf (actual size)



100 millimeters

Oak leaf (actual size)



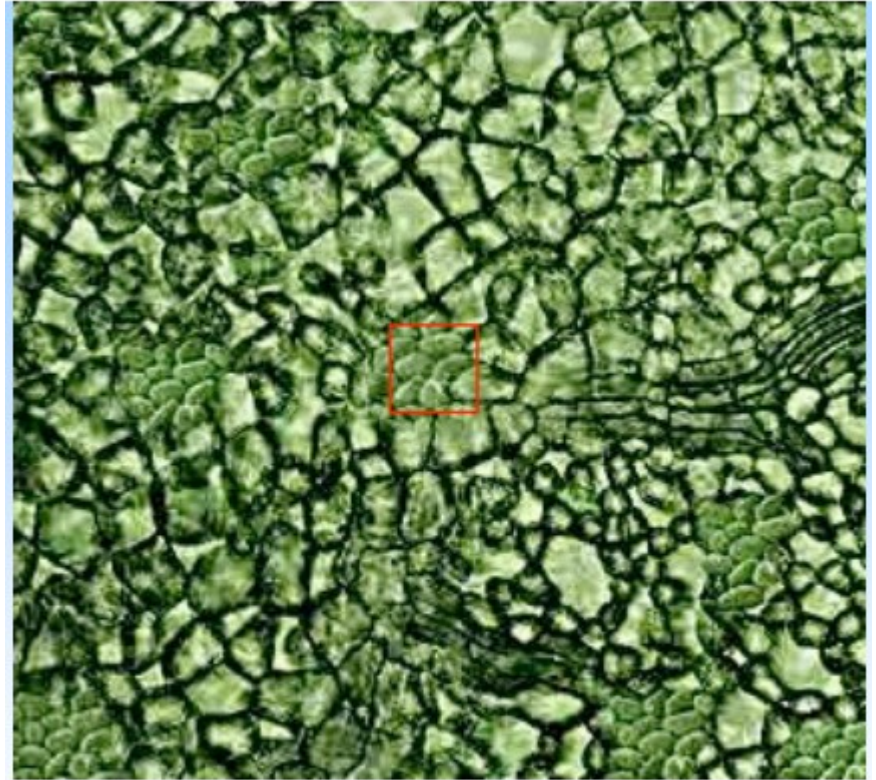
10 millimeters

Leaf surface, 10x enlarged



1 millimeter

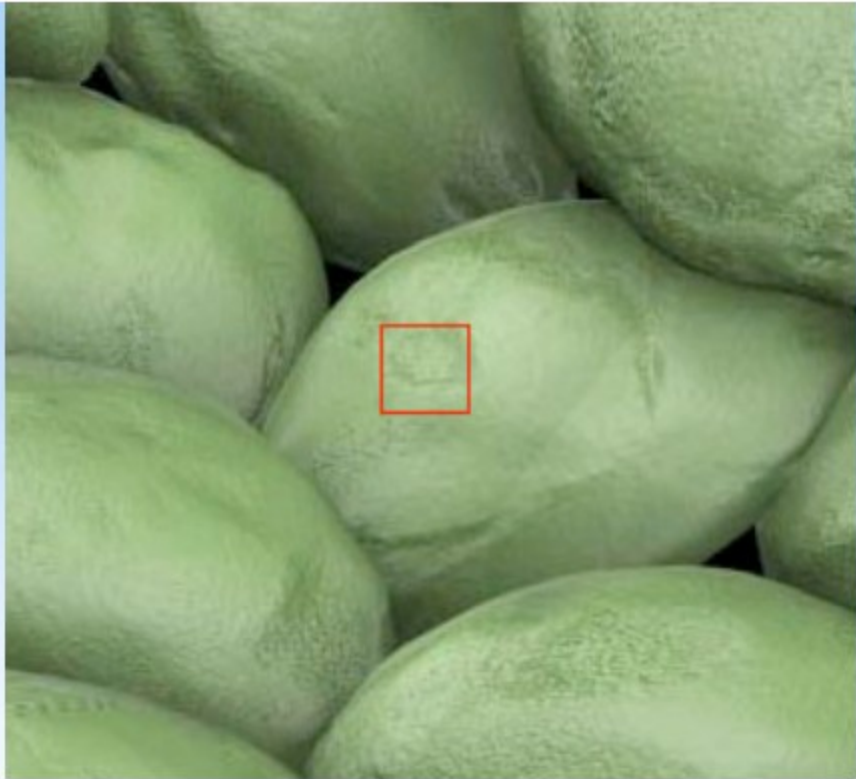
Leaf surface, 100x enlarged



100 microns

Many cells

HUMAN HAIR



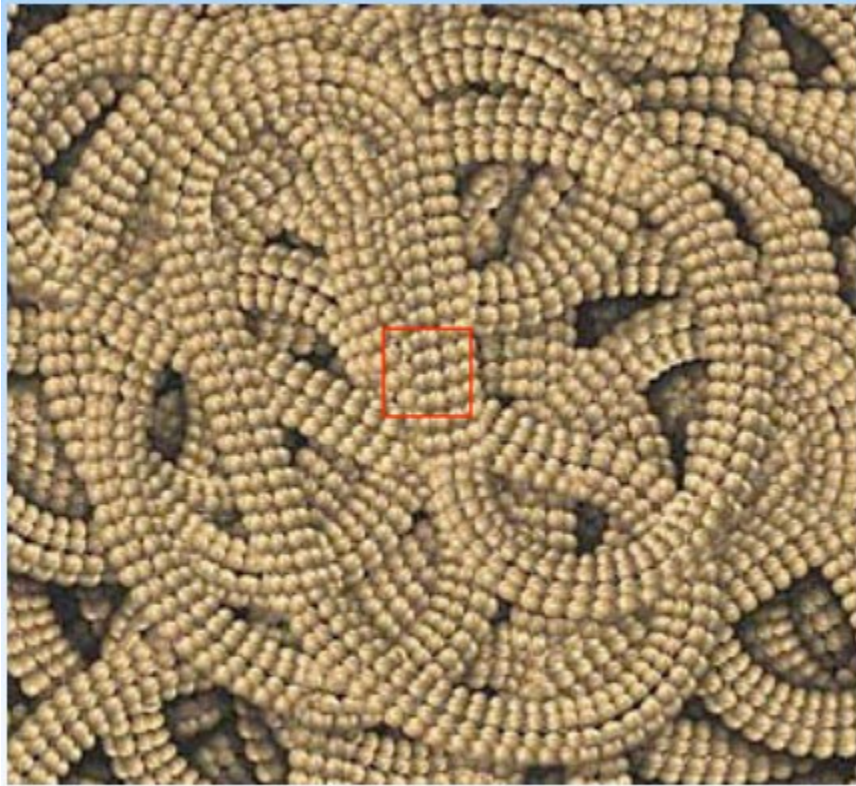
10 microns

Individual cells



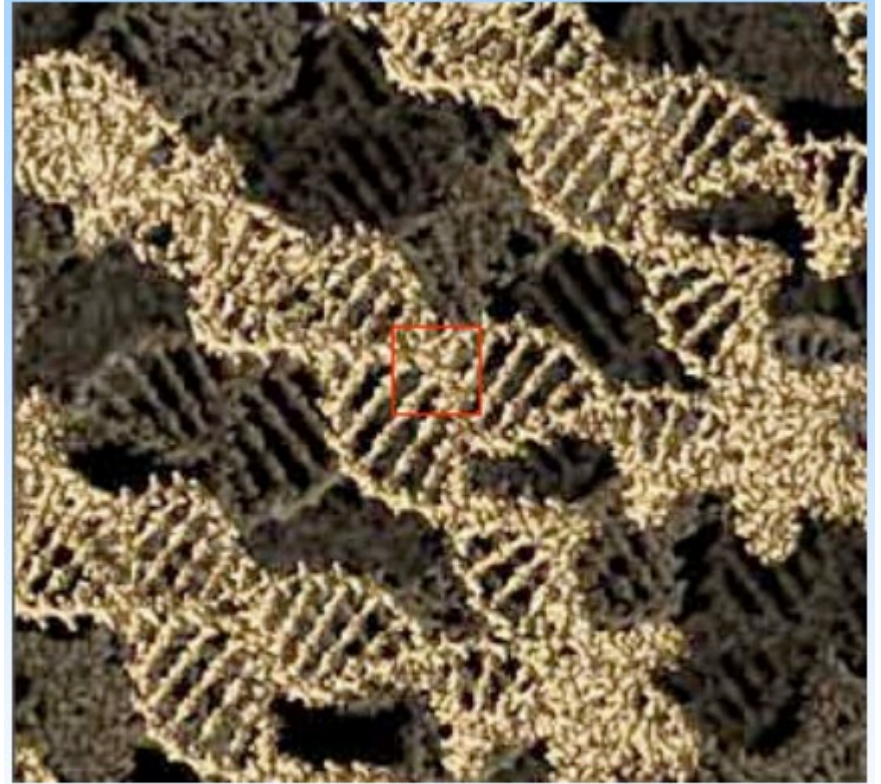
1 micron

Cell nucleus



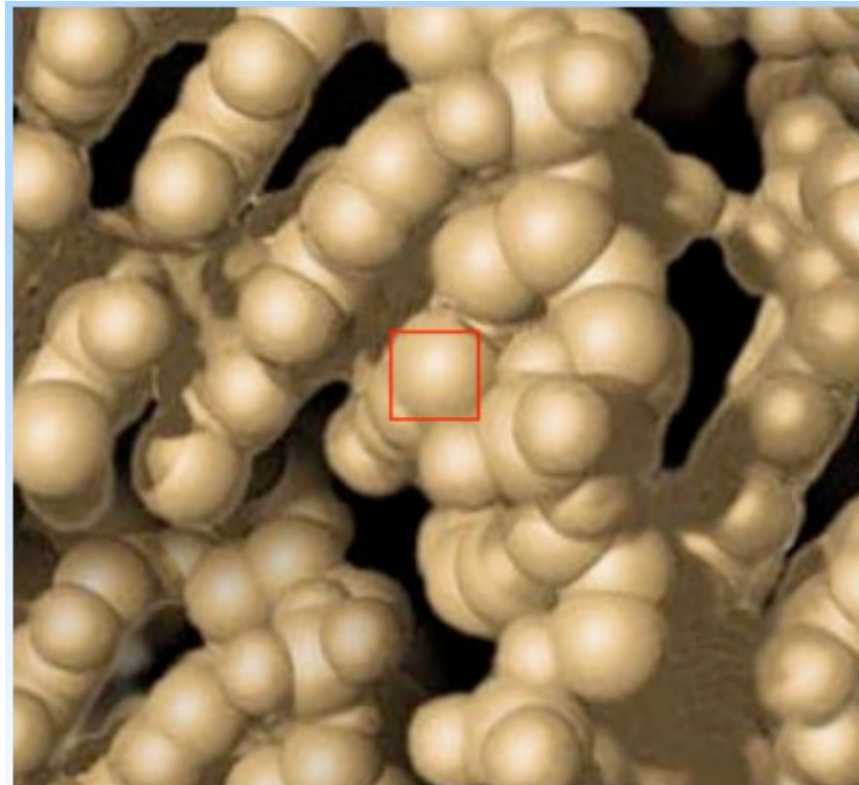
100 nanometers

Chromatin structure



10 nanometers

DNA double strands



1 nanometer

Individual molecules and atoms

The history

- **The Vision:** In 1959, Caltech physicist Richard Feynman gives his famed talk “There’s Plenty of Room at the Bottom,” outlining the prospects for atomic engineering.
- **Seeing is Believing:** In 1981, Gerd Binnig and Heinrich Rohrer of IBM’s Zurich Research Laboratory create the scanning tunneling microscope, enabling researchers to both see and manipulate atoms for the first time.
- **Nanostructures:** In 1985, Robert F. Curl Jr., Harold W. Kroto, and Richard E. Smalley discover buckminsterfullerenes (buckyballs — refer to Figure 1-1), soccer-ball-shaped molecules made of carbon and measuring roughly 0.7nm wide.

There's Plenty of Room at the Bottom

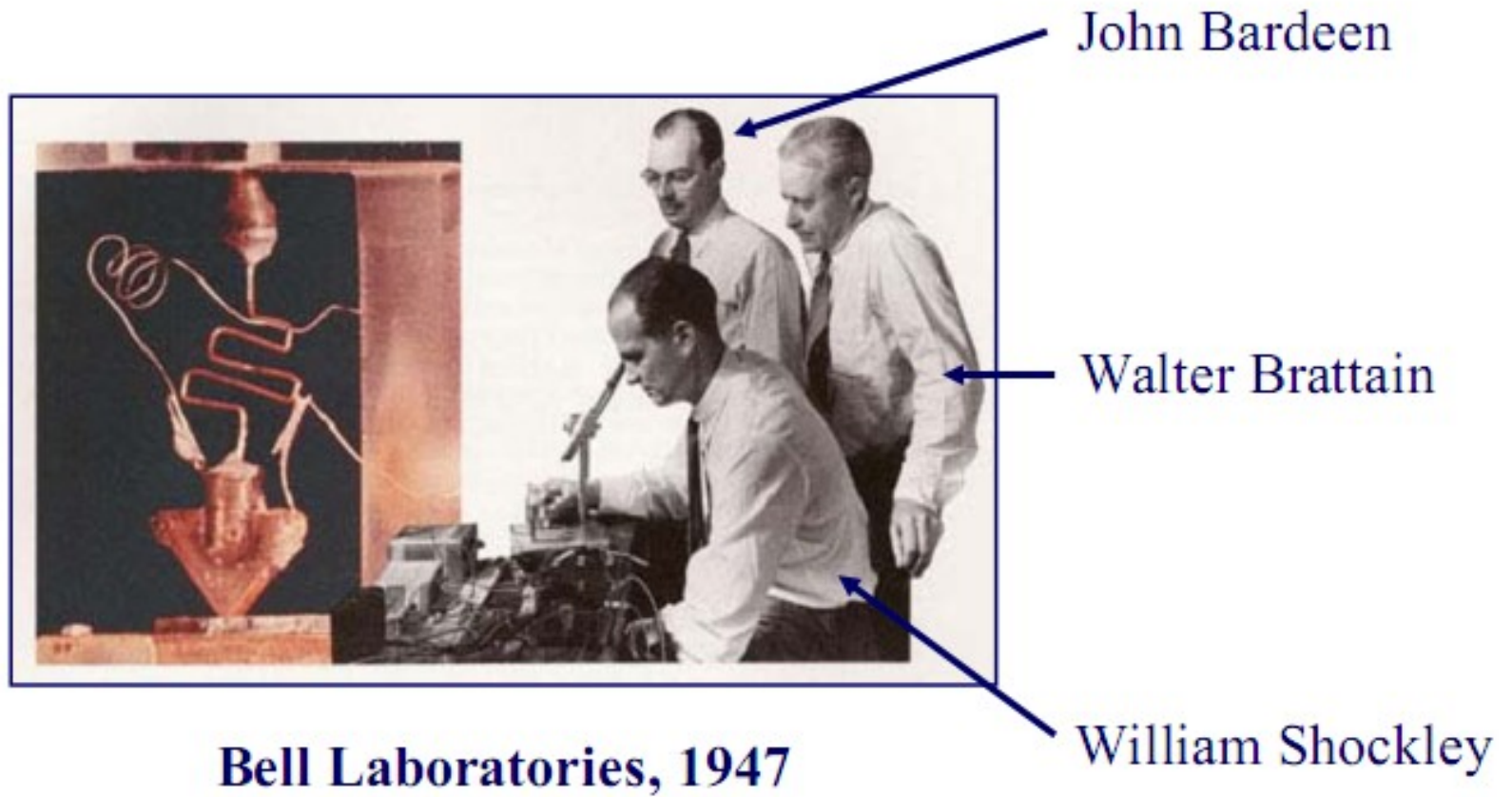


Richard Feynman
Cal Tech, 1959

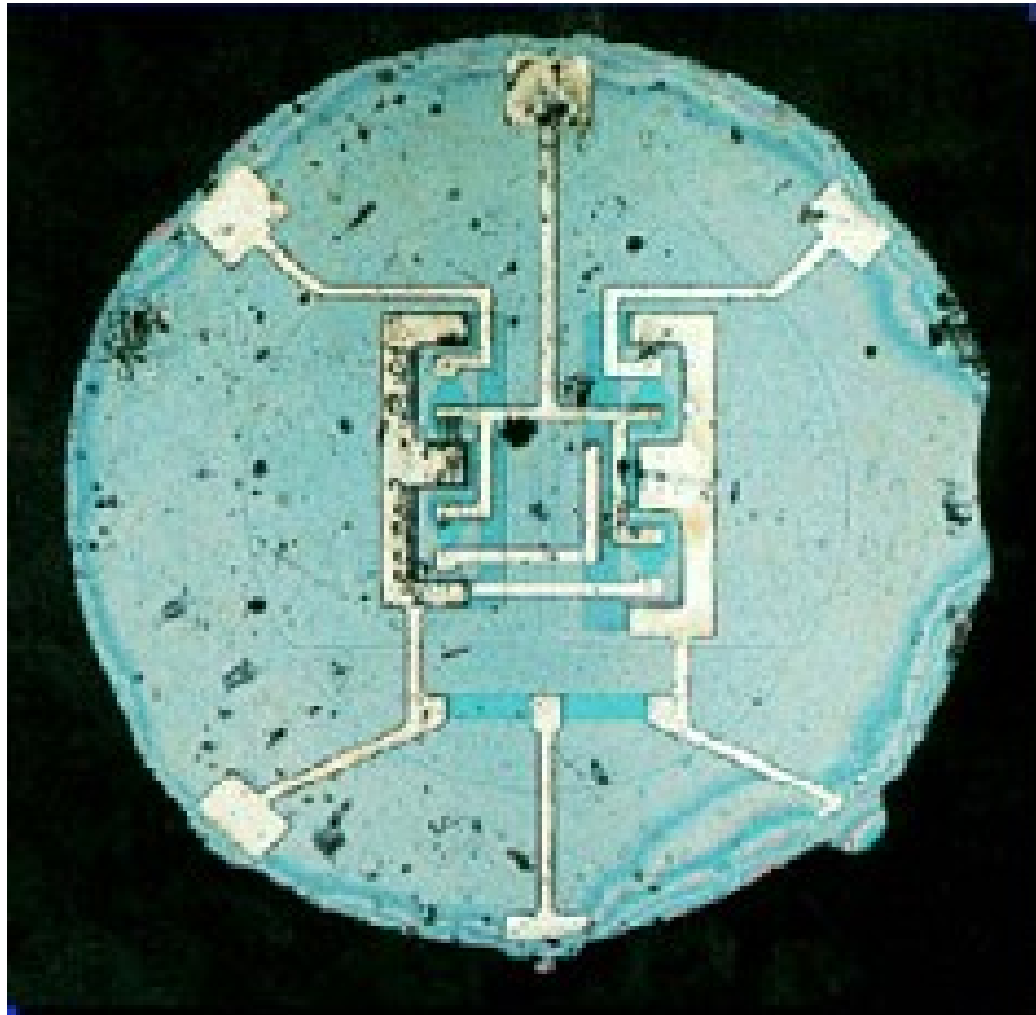
“People tell me about miniaturization, and how far it has progressed today. They tell me about electric motors that are the size of the nail on your small finger. And there is a device on the market, they tell me, by which you can write the Lord's Prayer on the head of a pin. But that's nothing; that's the most primitive, halting step in the direction I intend to discuss. It is a staggeringly small world that is below. In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction. Why cannot we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?”

This goal requires patterning at the 10 nanometer scale.

Invention of the Transistor



The first planar integrated circuit, 1961



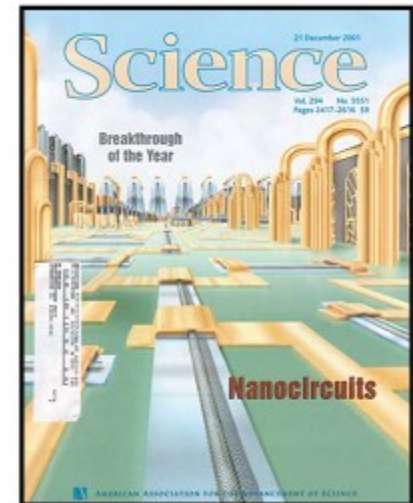
2001: A Nanotechnology Odyssey



July 23, 2001



September, 2001

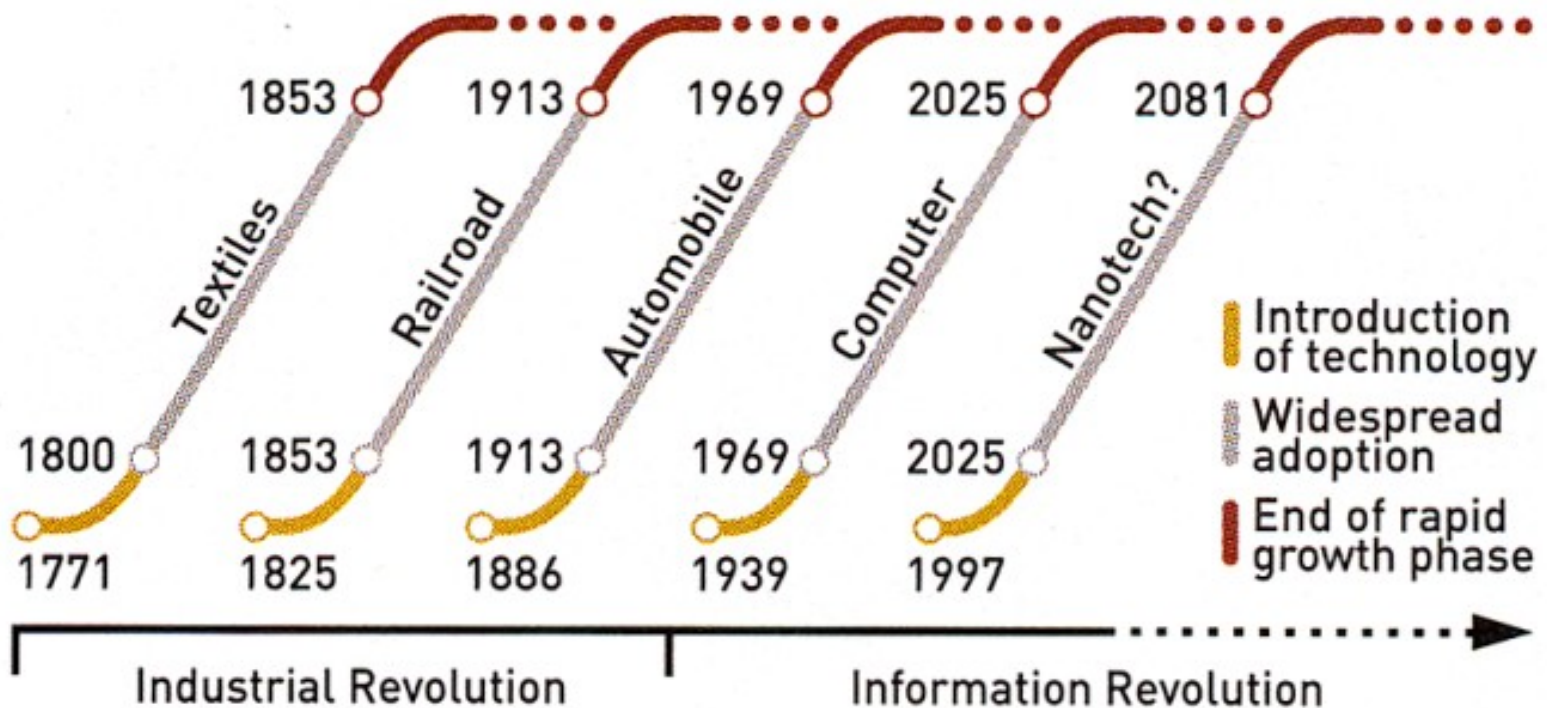


December 21, 2001



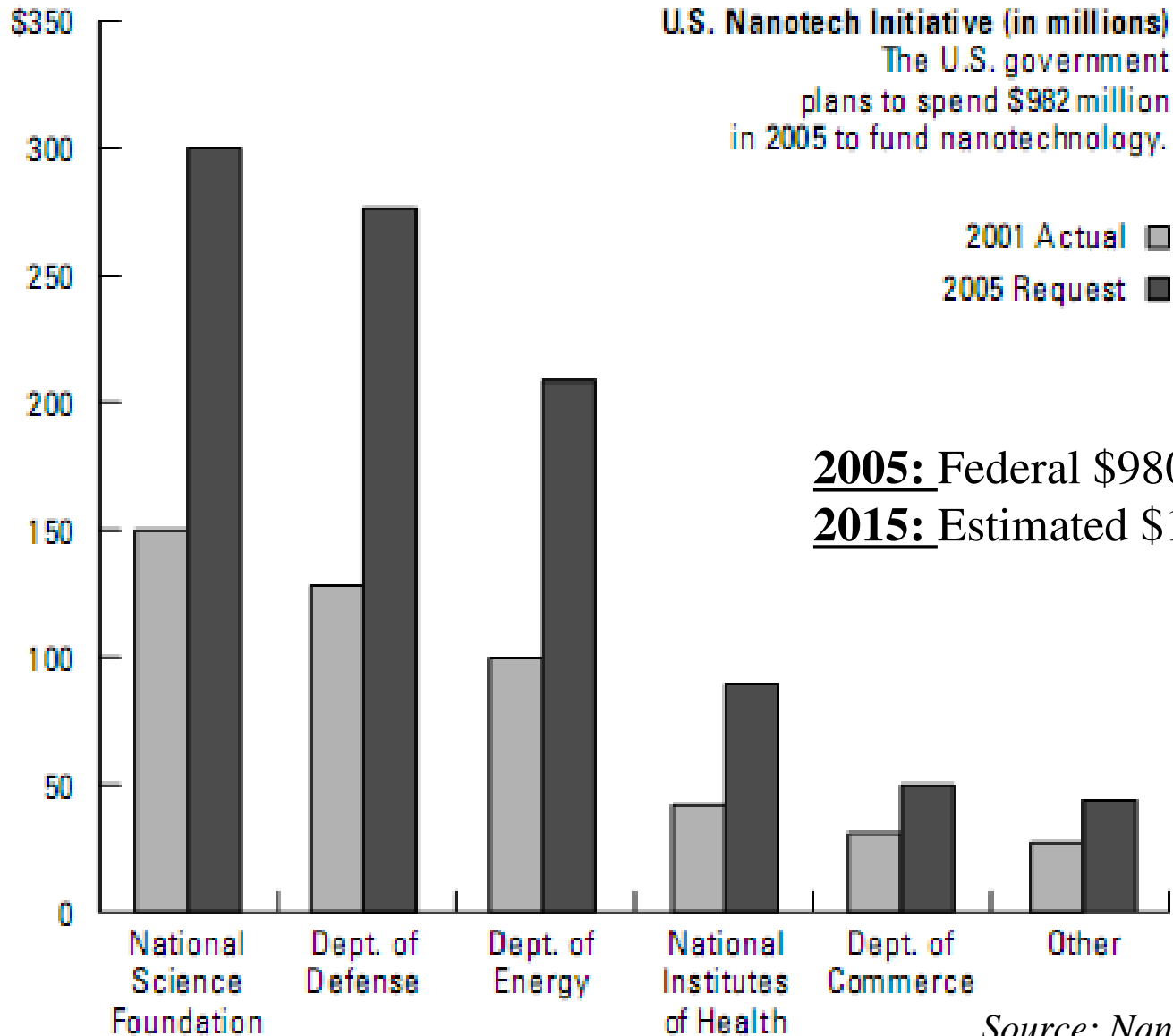
REVOLUTIONARY FORCES

Basic advancements in science and technology come about twice a century and lead to massive wealth creation.



Funding in nanotechnology industry

The nanotech industry



Source: Nanotechnology For Dummies

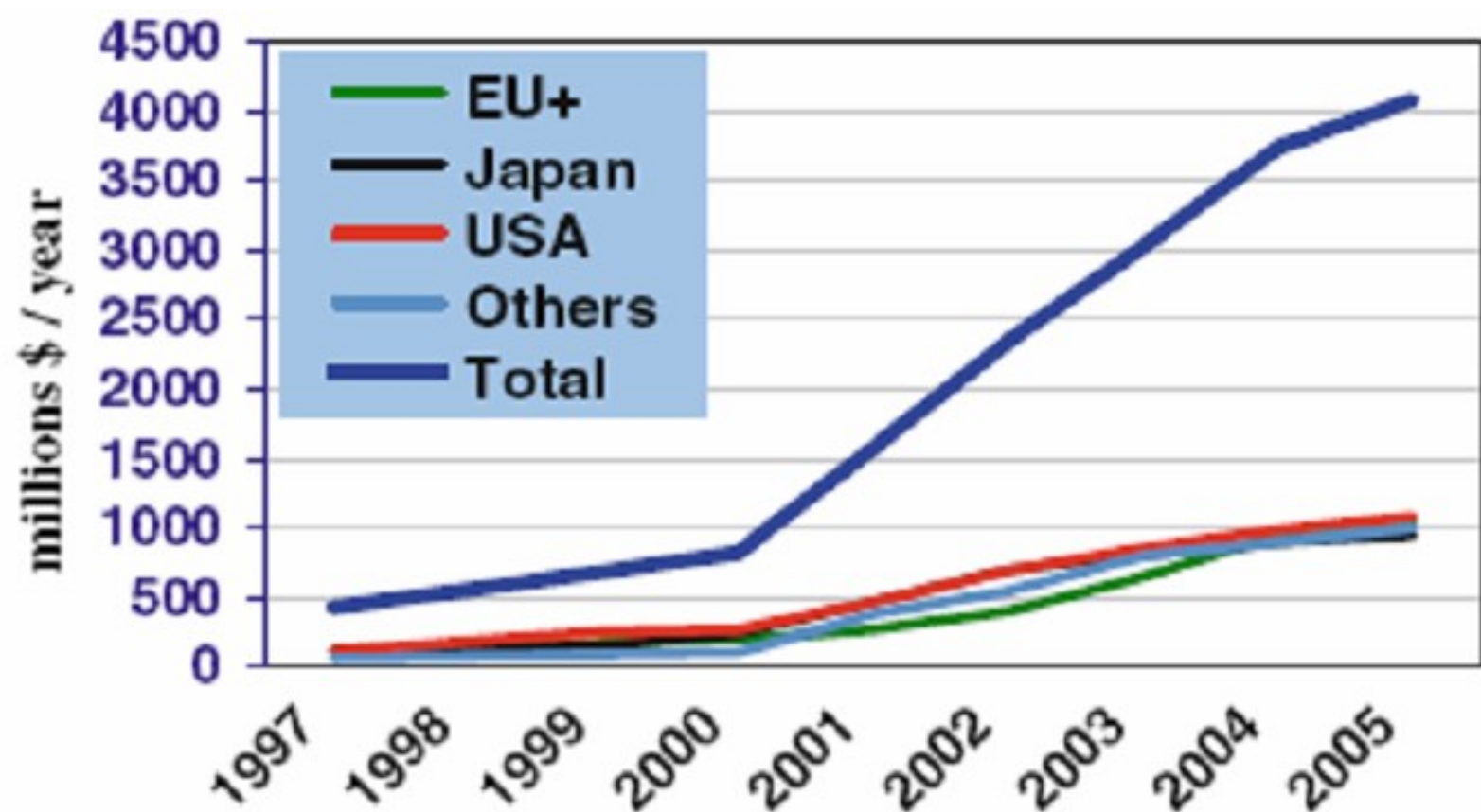
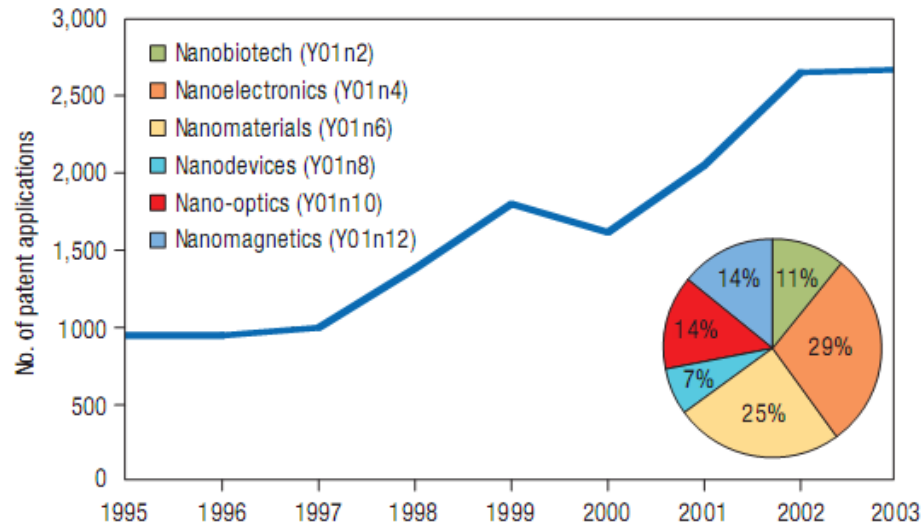
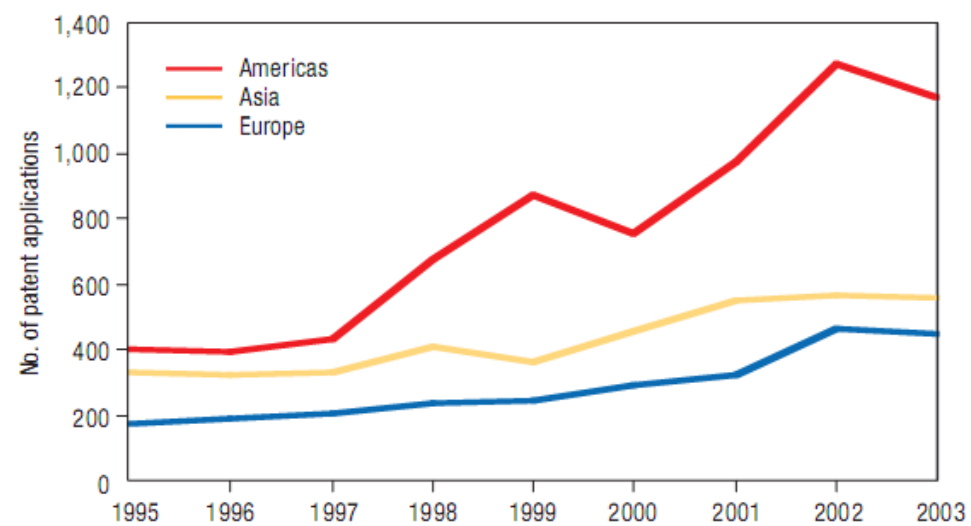


Figure 3. National government (and EU) investments in nanotechnology R&D in the past nine years (1997–2005)

a**b**

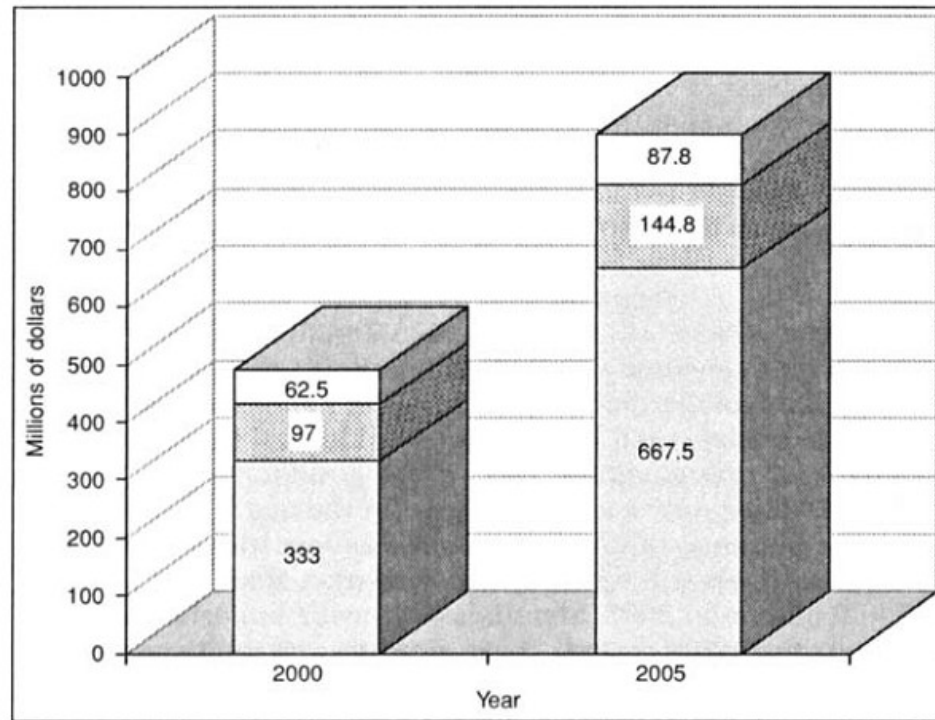
Total number of patent applications in nanotechnology between 1995 and 2003, and (inset) the proportion of applications in 2003 in six subfields defined by the European Patent Office. b, Number of patent applications from the Americas, Asia and Europe.

The world according to nano

Nano Investment		
Country	2003 Nanotech Funding in Millions of Dollars	Percent from National Government
Japan	1,610	50
U.S.	1,524	51
China	480	58
South Korea	280	71
Germany	218	54
Australia	193	48
U.K.	160	56
World Total	5,544	52

Market Analysis - Major Results

Source: Business Communication Co. Inc.



Nanoparticle world market by application area. Total 2000 market was \$492.5 million. Total 2005 market expected to be \$900.1 million. (a) energy, catalytic and structural applications; (b) biomedical, pharmaceutical and cosmetic applications; and (c) electronic, magnetic and optoelectronic applications).

A FEW TARGETS FOR NANOSCIENCE/TECHNOLOGY

- ADVANCED MATERIALS
- FIVE-MINUTE HEALTH SWAB TEST
- INTERACTIVE GLUCOSE SENSING, DOSING
- HUMAN REPAIR
- OPTICAL COMPUTERS
- GREASELESS SUNTAN LOTION
- NONFREEZING WINDSHIELDS
- STAINLESS TIES FOR SOUP SPILLERS
- SELF-MONITORING FOOD PACKAGING
- NEURONAL INTERFACES
- FULLY TARGETED DRUG DELIVERY
- HEATLESS LIGHT
- TRULY EFFICIENT SOLAR RADIATION CAPTURE

True or False?

We should close this office.. Everything that needs to be invented, is already..

Director, US Patent Office, 1929

A few computers should be enough for the society!

Watson (IBM Watson Center fame)

640k should be enough for everyone!

Bill Gates, 1982

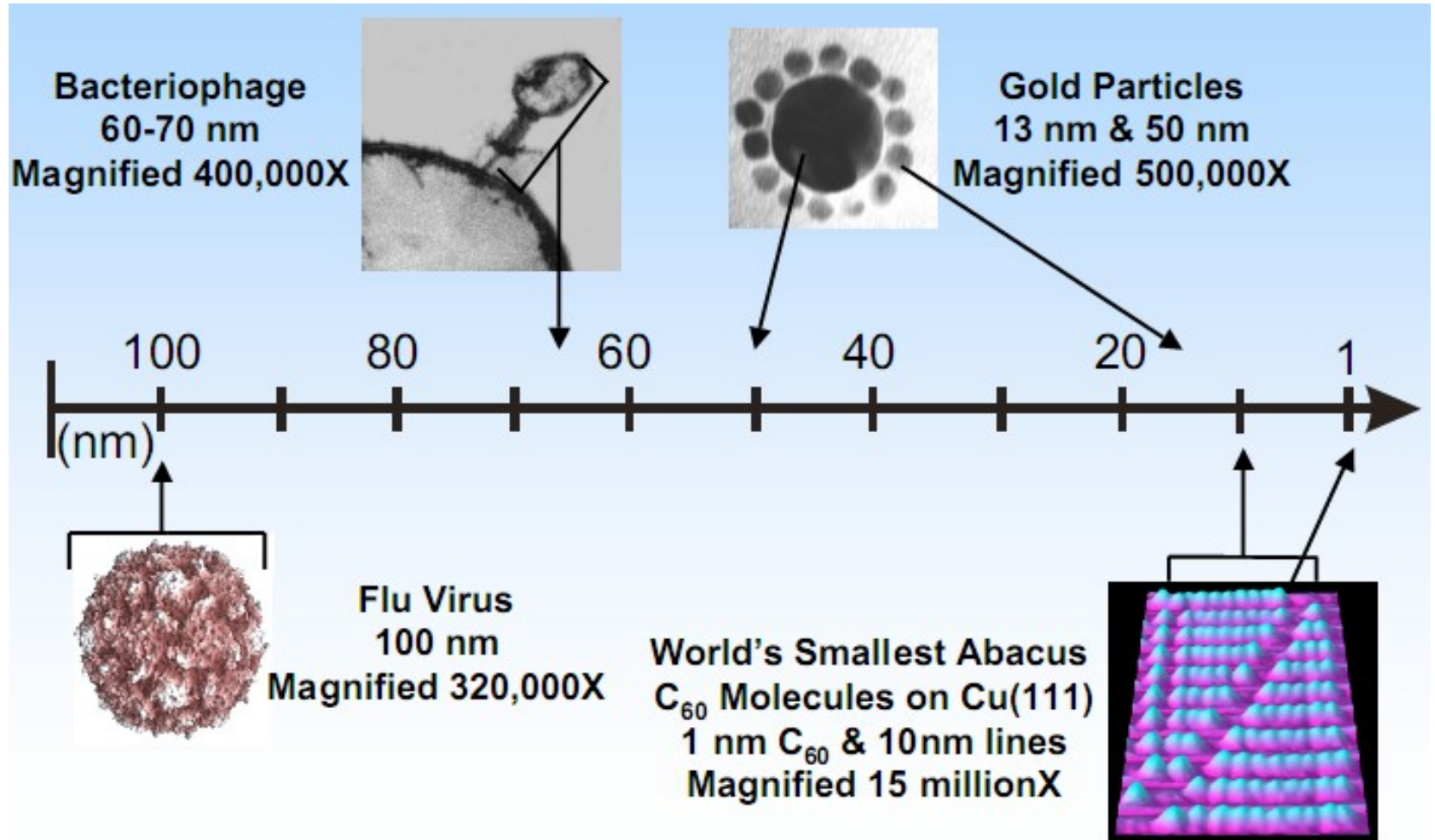
Infectious diseases is now history..

Surgeon General, 1959

Technology Outlook

High Volume Manufacturing	2004	2006	2008	2010	2012	2014	2016	2018
Technology Node (nm)	90	65	45	32	22	16	11	8
Integration Capacity (BT)	2	4	8	16	32	64	128	256
Delay = CV/I scaling	0.7	~0.7	>0.7	Delay scaling will slow down				
Energy/Logic Op scaling	>0.35	>0.5	>0.5	Energy scaling will slow down				
Bulk Planar CMOS	High Probability				Low Probability			
Alternate, 3G etc	Low Probability				High Probability			
Variability	Medium			High		Very High		
ILD (K)	~3	<3	Reduce slowly towards 2-2.5					
RC Delay	1	1	1	1	1	1	1	1
Metal Layers	6-7	7-8	8-9	0.5 to 1 layer per generation				

The Interesting Length Scale



size-dependent behaviors

Size-Dependent Properties

- At the nanometer scale, properties become size-dependent. For example,
 - (1) Thermal properties – melting temperature
 - (2) Mechanical properties – adhesion, capillary forces
 - (3) Optical properties – absorption and scattering of light
 - (4) Electrical properties – tunneling current
 - (5) Magnetic properties – superparamagnetic effect

New properties enable new applications

At the nanoscale ...

Properties can become
SIZE-DEPENDENT

EXAMPLES –
STAINED GLASS
MELTING POINTS OF METAL NANODOTS

Melting Temperature

Nanocrystal size decreases



surface energy increases



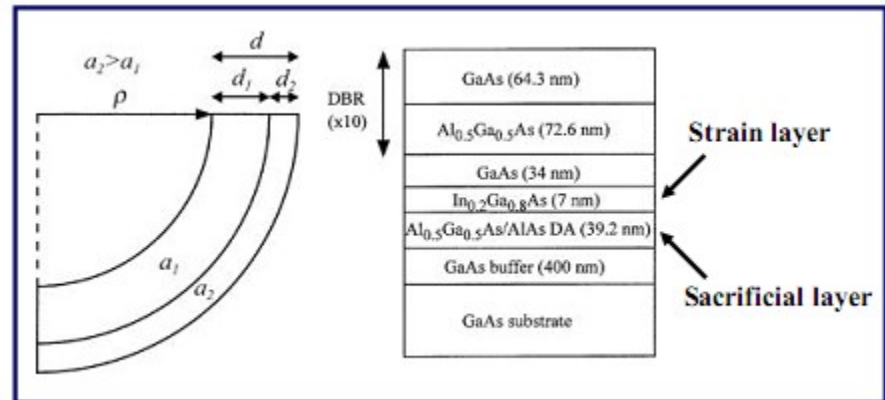
melting point decreases

e.g., 3 nm CdSe nanocrystal melts at 700 K
compared to bulk CdSe at 1678 K

Mechanical Properties

- At the nanoscale, surface and interface forces become dominant. For example,

- (1) Adhesion forces
- (2) Capillary forces
- (3) Strain forces



Surface coatings are extremely important to prevent sticking in nanoscale electro-mechanical systems (NEMS)

Optical Absorption



Figure 1. Gold building blocks, from the atomic to the mesoscopic, and their changing colors.

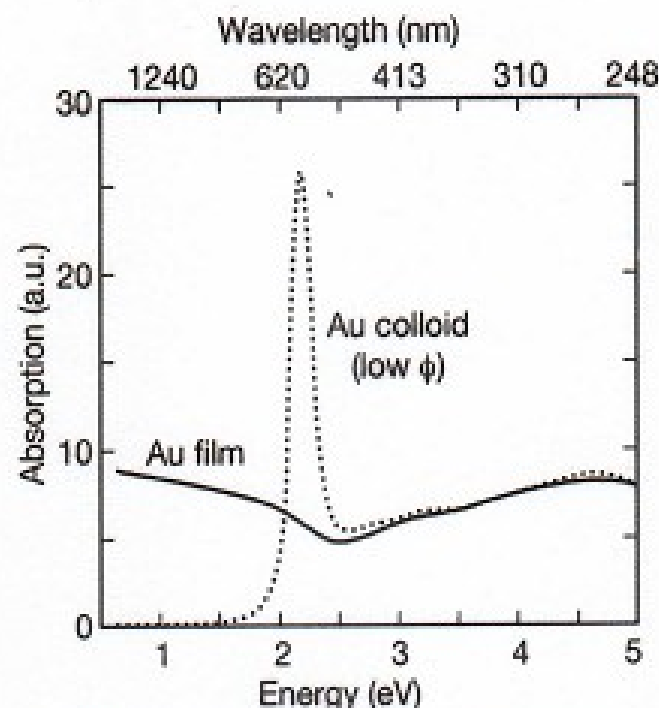
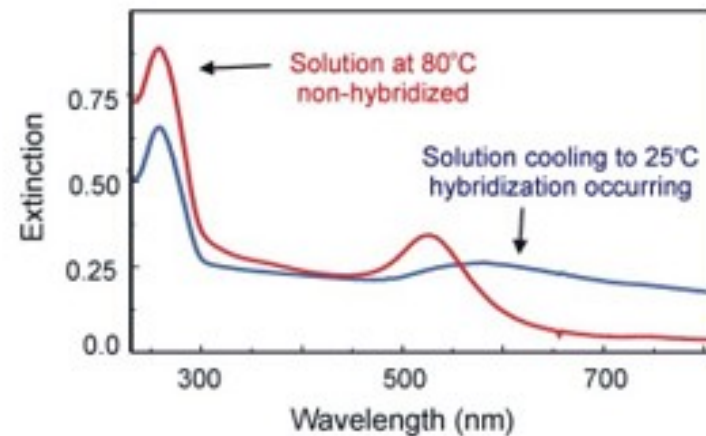
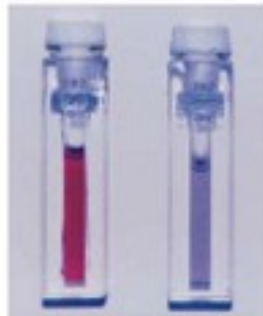
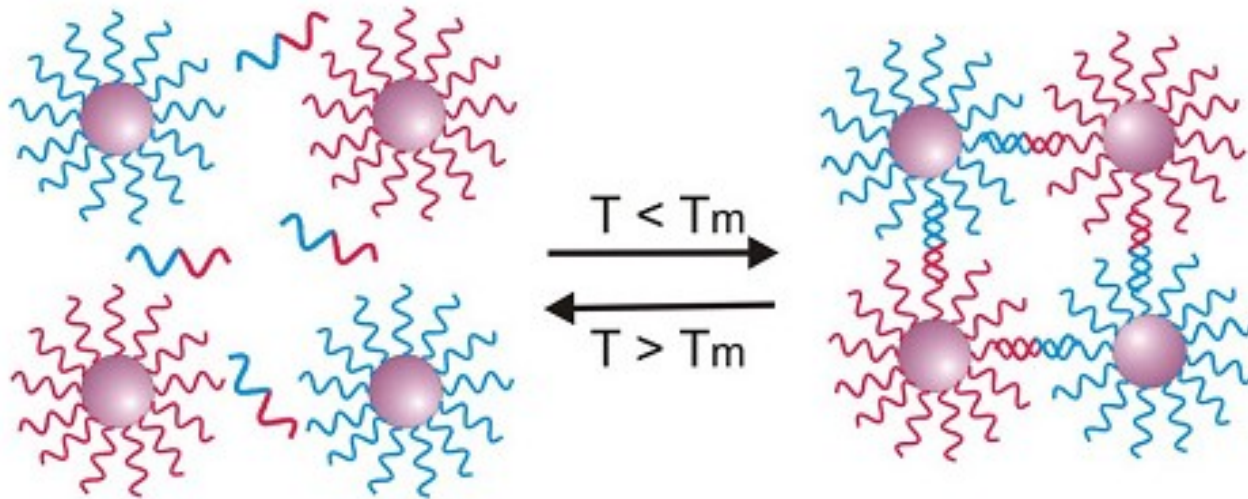


Figure 3. Absorption spectra of a gold nanocrystal film and a thin, bulk gold metal film of equivalent thickness. ϕ is the volume fraction of gold in the sample.

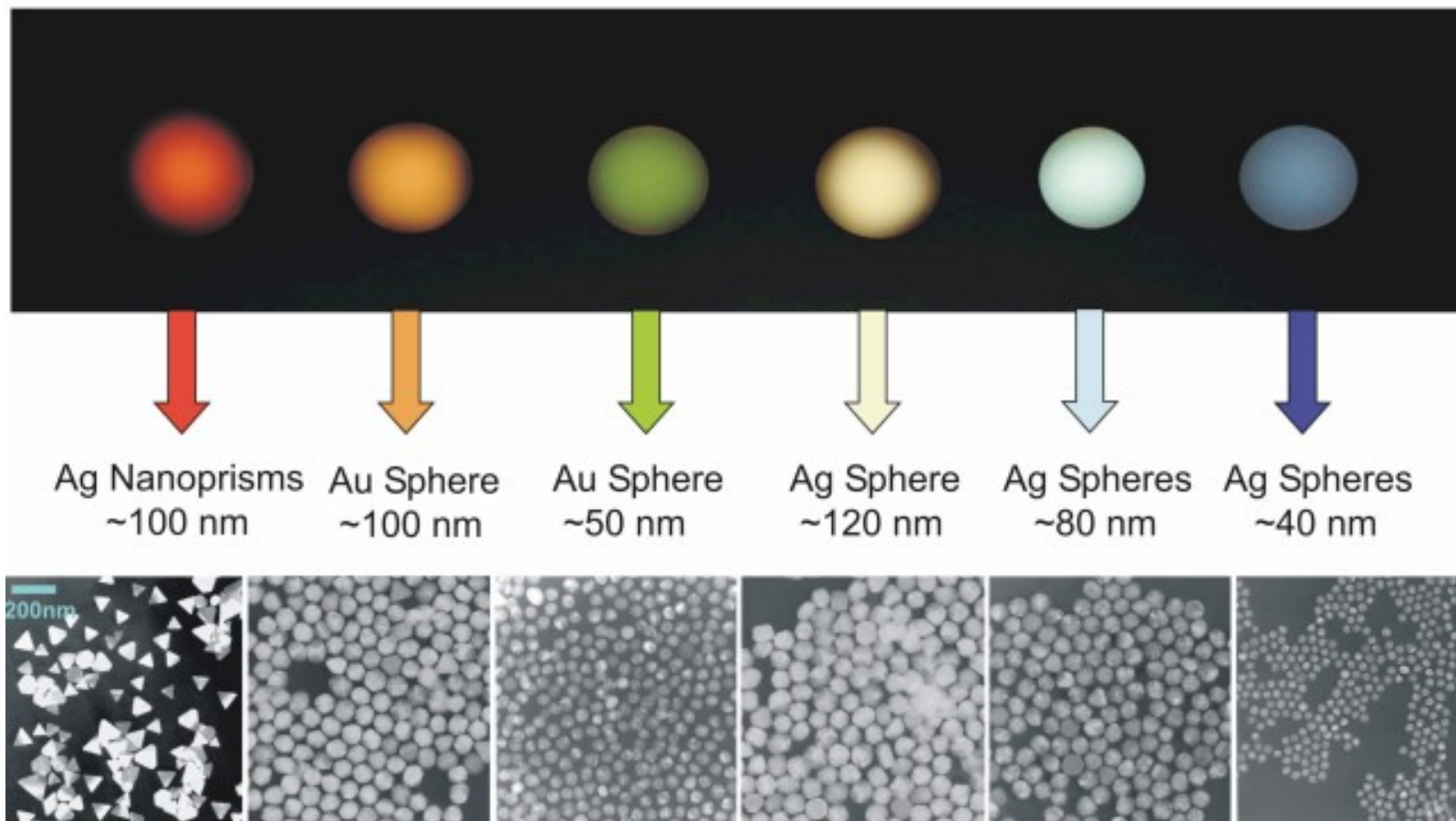
Modern Use of Nanoparticles: Biosensors



Electrical Properties: Tunneling Current

- At the nanometer scale, electrical insulators begin to fail to block current flow.
- Quantum mechanical effect known as tunneling.
- Tunneling current increases exponentially as the thickness of the insulator is decreased.
- Tunneling is the basis of the scanning tunneling microscope and covalent chemical bonding.

Rayleigh Light-Scattering of Nanocrystals: Shape, Size, and Composition Matter



* The scale bar is the same for all the images.

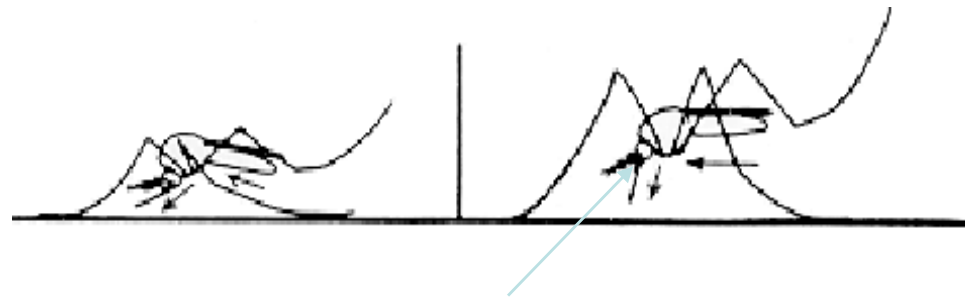
Mirkin lab

Why Nano

- The discovery of novel materials, processes, and phenomena at the nanoscale, as well as the development of new experimental and theoretical techniques for research provide fresh opportunities for the development of innovative nanosystems and nanostructured materials. Nanosystems are expected to find various unique applications. Nanostructured materials can be made with unique nanostructures and properties. This field is expected to open new venues in science and technology

Why miniaturization?

- Minimizing energy and materials use in manufacturing
- Redundancy and arrays
- Integration with electronics, simplifying systems (e.g., single point vs. multipoint measurement)
- Reduction of power budget
- Faster devices
- Increased selectivity and sensitivity
- Wider dynamic range
- Exploitation of new effects through the breakdown of continuum theory in the microdomain
- Cost/performance advantages
- Improved reproducibility (batch concept)
- Improved accuracy and reliability
- Minimal invasive (e.g. mosquito project)
- Do we have a choice? (see next viewgraph- - the Law of Accelerating Returns)



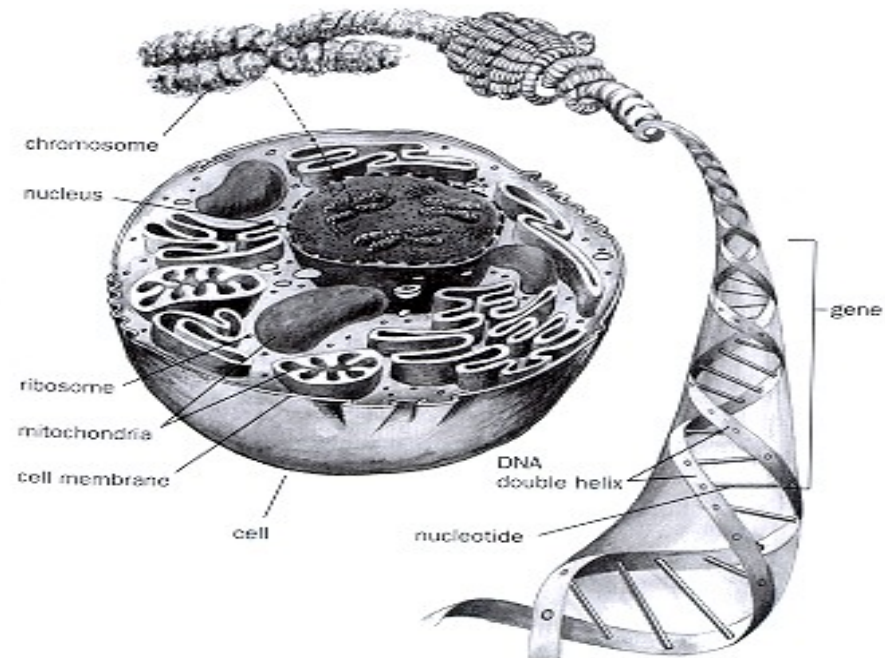
proboscis is about $75 \mu\text{m}$ ϕ

Why miniaturization?

- Evolution (sophistication) of life-forms or technology speeds up because they are build on their own recorded degree of order. Ray Kurzweil calls this The Law of Accelerating Returns*
- This Law of Accelerating Returns gave us ever greater order in technology which led to computation -- the essence of order.
- For life-forms DNA provides the record. In the case of technology it is the ever improving methods to record information.
- Moore's law ** (based on a temporary methodology i.e., lithography) is only an example of the Law of Accelerating Returns. Beyond lithography we may expect further progress in miniaturization based on DNA, quantum devices, AFM lithography, nanotubes, etc.

*Ray Kurzweil in The Age of Spiritual Machines

** See next viewgraph



Why miniaturization?

- Moore's 'Law': The observation that the logic density of silicon integrated circuits (ICs) has followed a curve (bits per square inch/transistors) = $2^{(t-1962)}$ where t is the year. The amounts of information storable on a given amount of silicon roughly doubled every year since the technology was invented. This relation, first mentioned in 1964 by semiconductor engineer Gordon Moore (who co-founded Intel four years later) held until the late 1970s, at which point the doubling period slowed to 18 months. The doubling period remained at that value up to late 1999. Moore's Law is apparently self-fulfilling.

Assignment

Explain the Size-Dependent Properties of materials in nano scale.

nanohub.org

Submit the soft copy at website.

And Hard copy at the class, 13 Feb

Make up class

13 February 2010

10AM-12PM